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Fieldable Impulsive Source and Timer (FIST)

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1. Overview

This document describes the Fieldable Impulsive Source & Timer (FIST). The key features of FIST are:

- All-in-one carrying case, total weight < 20 lb
- Portable self-contained battery-operated unit for outdoor use
- Low-power short duration impulsive electrical signal to stimulate a device under test (DUT)
- Output timing controlled by a GPS receiver
- Auxiliary timing output

Major features and characteristics of FIST are summarized in Table 1.

Name	Basic Characteristics	Operation
FIST	<ul style="list-style-type: none"> • Battery operation • Integrated GPS receiver to provide timing discipline • Custom Los Alamos built impulse generator (pulser) • Pulse characteristics <ul style="list-style-type: none"> ○ Pulse duration ~ 3 μs; Pulse repetition rate \leq 1Hz ○ Frequency: 1-40 MHz ○ Peak voltage < 2kV; Stored energy < 10 mJ ○ Peak power (averaged during impulse period) ~ 3 kW • Primary pulse coupling mechanism <ul style="list-style-type: none"> ○ Conductive low-impedance cable to the grounding point of DUT • Secondary pulse coupling mechanism <ul style="list-style-type: none"> ○ Whip antenna with characteristics frequency ~ 30 MHz ○ Radiation pattern: horizontal toroid; estimated antenna gain: 1 ○ Estimated peak power at 10 km < 3 μW/m² ○ 0.1-s average power at 10 km < 100 pW/m² broadband 	<ul style="list-style-type: none"> • Portable outdoor • DUT operation check • DUT timing check

Table 1. Summary of FIST features and output, including potential RF emission

2. FIST Major Components and Parts List

Table 2 lists the major components and parts list. The impulse generator (pulser) is designed and built by Los Alamos National Laboratory (LANL). All other parts are commercial-off-the-shelf (COTS).

Part Name	Manufacturer	Part No.	Qty
Pelican Laptop Case 1470	Pelican-case	1470-TAN	1
TM-4M/D receiver	Spectrum Instruments	20381-901	1
TM-4M receiver GPS Antenna, 5m cable	Spectrum Instruments	60014-003	1
Impulse generator, +12V DC, triggered impulse out	LANL	MiniCal-1d2c	1
Coupling Cable, Metallic Braid, 1/4", 3.75 m	Glenair Inc	100-003-A125	1

Table 2. FIST major components and parts list

Figure 1 shows the layout of the major components in the FIST carrying case. The exact layout in the carrying case in different units may differ.

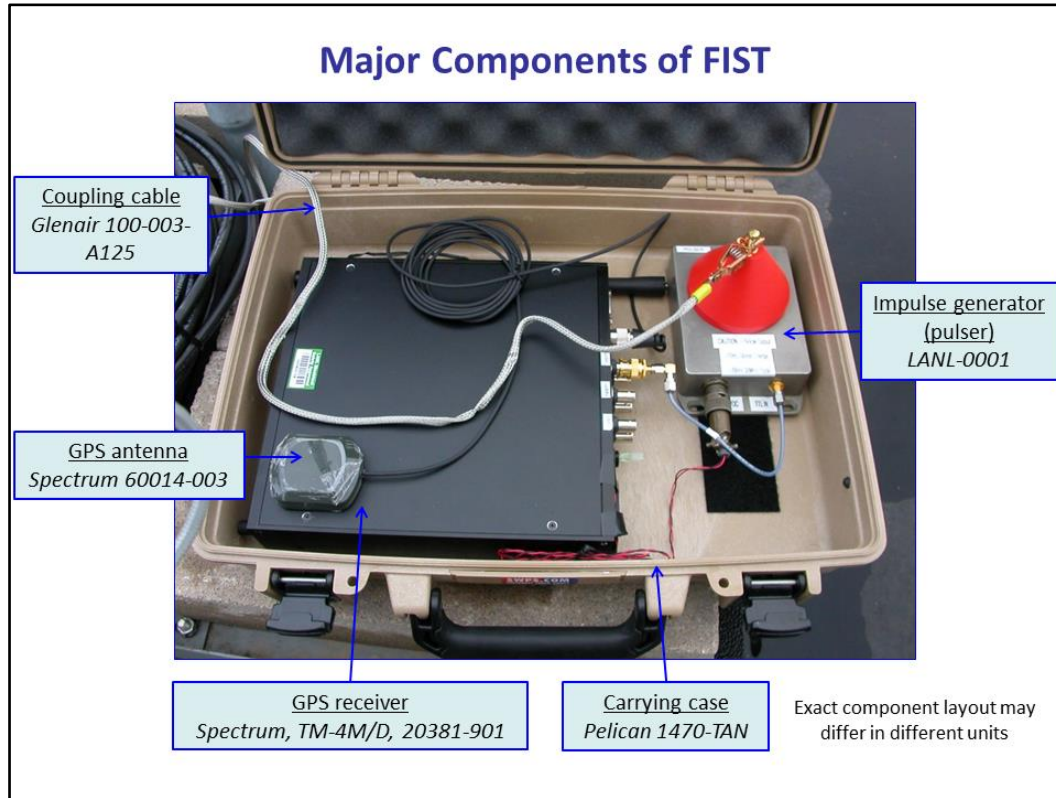


Figure 1. Major components and layout in the FIST case.

3. Output Assessment of FIST

3.1. Energy output/safety

- 3.1.1. The stored energy in the FIST per pulse is limited to < 10 mJ.
- 3.1.2. Typical energy content of an electrical static discharge is tens of mJ.
- 3.1.3. This unit is within the safety boundary of low-hazard electrical device defined in Los Alamos National Laboratory electrical safety standard.
- 3.1.4. FIST is designed to be used by trained and authorized personnel. It is not designed to be used on or near sensitive electronics devices susceptible to electrical static discharge damage.

3.2. Radiated emission

- 3.2.1. FIST is designed to be used in close proximity to the device under test (DUT). Primary impulse injection is through conductively coupled low-impedance cable to the DUT's grounding system. FIST does have a secondary coupling mechanism through an antenna, designed for portability and not for efficiency.
- 3.2.2. Assuming a perfect antenna, the FIST's radiation characteristics are as follows.
 - 3.2.2.1. Impulse is ~ 3 μ s in duration.
 - 3.2.2.2. Impulse is between 1-40 MHz.

- 3.2.2.3. Estimated peak power is $< 3 \mu\text{W}/\text{m}^2$ at 10 km distance.
- 3.2.2.4. Estimated average power is $< 100 \text{ pW}/\text{m}^2$ at 10 km distance over 0.1 second, following FCC's impulsive source calculation methodology.
- 3.2.3. Other known manmade and natural RF radiation sources include the following.
 - 3.2.3.1. KKOB 770AM radiates 50 kW at 770 KHz. This narrow band ($< 20 \text{ kHz}$ wide) CW signal level is $40 \mu\text{W}/\text{m}^2$ at 10 km distance.
 - 3.2.3.2. KUNM 89.9FM radiates 21.5 kW at 89.9 MHz. The CW signal level is $18 \mu\text{W}/\text{m}^2$ at 10 km distance.
 - 3.2.3.3. KOAT Channel 7 broadcasts digital signals at 26.5 kW between 174 & 180 MHz. The digital signal level over the 6MHz bandwidth is $21 \mu\text{W}/\text{m}^2$ at 10 km distance.
 - 3.2.3.4. Natural RF transient background: Typical lightning's peak power is estimated to be TeraWatt (10^{12}W) for about 30 μs (<http://en.wikipedia.org/wiki/Lightning>), mostly as dissipated heat. A lightning stroke is estimated to impart an RF transient with a peak radiated power of $\sim 10 \text{ mW}/\text{m}^2$ at 10 km distance.
- 3.2.4. Summary & Conclusion
 - 3.2.4.1. FIST's maximum time-averaged radiated emission is more than 1000 times weaker than the typical RF broadcast, even without accounting for the considerable bandwidth difference of a factor of 10-1000.
 - 3.2.4.2. FIST's peak RF transient emission is more than 30,000 times weaker than from a lightning stroke.
 - 3.2.4.3. Conclusion: FIST's radiated output is significantly lower, by at least a factor of 1000, than manmade CW broadcast source and natural RF transients.

4. Operation & Maintenance

4.1. Setup

- 4.1.1. Find an outdoor dry and preferentially elevated spot near the DUT. Avoid moisture or condensation. Avoid tall obstructions that may block the sky view and GPS reception.
- 4.1.2. Place the FIST case flat and open as shown in figure 2.
- 4.1.3. Identify/check/make the following switches and connections:
 - 4.1.3.1. The main power switch on the front panel (FP)
 - 4.1.3.2. DC power cable (twisted-pair) from the GPS receiver to the pulser.
 - 4.1.3.3. Coax trigger cable from the GPS receiver (BNC) to the pulser (SMA).
 - 4.1.3.4. Trigger cable connected to the GPS output column labeled 1PPM.
 - 4.1.3.5. The cable configuration depends on the transportation mode. Consult Section 4.2.8 for shipping/transportation guideline.
- 4.1.4. Identify the power control of the pulser
 - 4.1.4.1. Older FIST has a pulser power switch on the back panel.
 - 4.1.4.2. Newer FIST does not have a power switch on the back panel. Pulser is powered on/off by inserting/extracting the power plug to the back panel's +12V jack.
- 4.1.5. Connect the coupling cable
 - 4.1.5.1. Insert the coupling screw into the pulser's output port at the top of the dome.
 - 4.1.5.2. Use the alligator clips to attach the coupling cable to the pulser at one end and DUT's grounding point at the other.
 - 4.1.5.3. The coupling cable can snake but should not touch itself. It also should not touch other conductive parts or surfaces.

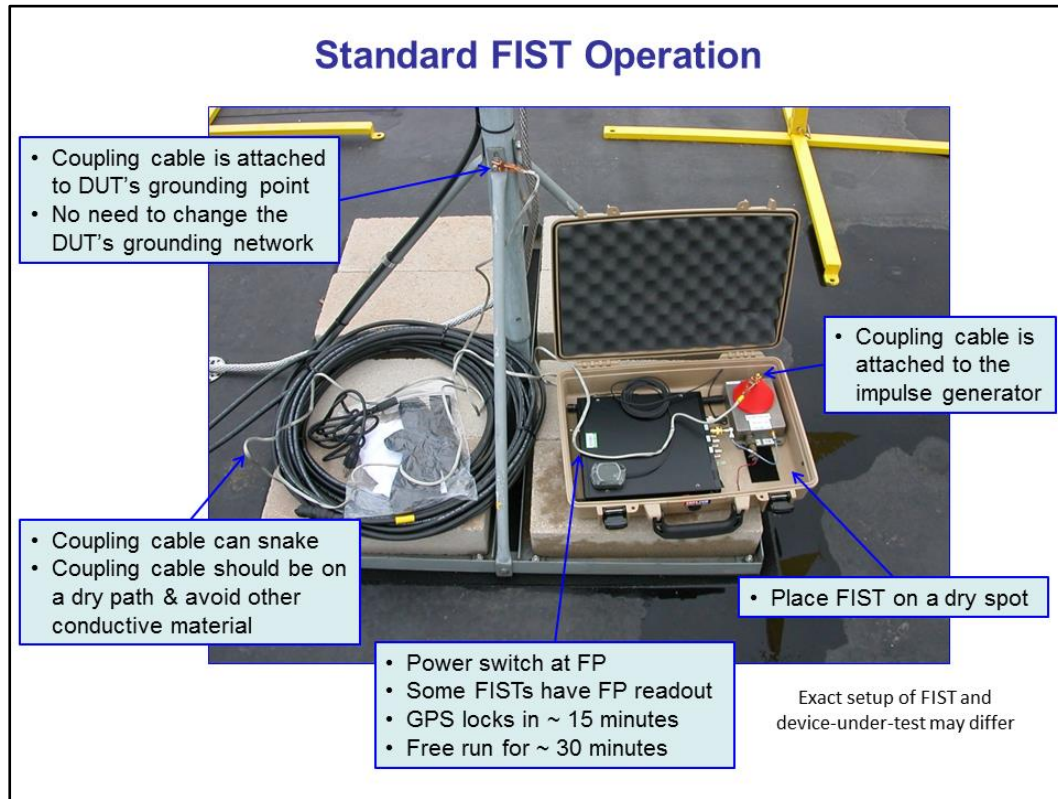


Figure 2. Typical FIST operation configuration.

4.2. Operation – (On/Ops/Off)

4.2.1. Double check the connections one last time and that the pulser is power off (see 4.1.4).

4.2.2. Power on: Turn on the power switch on the GPS receiver's front panel.

4.2.3. GPS timing quality check – *with* front panel display

4.2.3.1. Newer FISTs have a front panel display. Some displays have an intensity control knob on the right. Turn the knob to ensure that the reading is visible.

4.2.3.2. The display will indicate the GPS timing status. If it shows 888:88:88:88, the GPS receiver is not synchronized to an almanac nor locked: not useful for timing purposes.

4.2.3.3. Once FIST receives the almanac, the front panel begins to display meaningful numbers in DOY:HH:MM:SS UTC. The display will clearly show advancement of the second. FIST timing is good enough for use from this point forward.

4.2.3.4. For GPS receiver with front panel display knob, turn the display off after the GPS achieves usable timing to conserve battery life.

4.2.4. GPS timing quality check – *without* front panel display

4.2.4.1. Older FISTs has no front panel display, use LED status lights to determine GPS timing quality and lock status. Usable GPS timing is indicated by the absence of red light. GPS phase lock is indicated by two solid blue lights.

4.2.5. The GPS' time to first fix (TTFF) depends on many factors. It can be as short as a few minutes, and as long as tens of minutes, with 15 minutes being typical. If the GPS fails to give usable timing after 45-60 minutes, turn off the power and contact the FIST team.

4.2.6. After GPS achieves usable timing

4.2.6.1. Turn on the pulser using either the switch or power connector (4.1.4). The pulser has a light to indicate power on/off.

- 4.2.6.2. Let FIST free run for the desired duration. Typically 30 minutes.
- 4.2.6.3. FIST's internal battery should last 2 hours. Budget the operation accordingly.
- 4.2.6.4. If outdoor AC power is available and safe, plugging in the 120V AC power will keep the FIST charged and operating indefinitely.
- 4.2.7. Power off
 - 4.2.7.1. Turn off the master power on the GPS receiver. This turns off everything.
 - 4.2.7.2. Disconnect and store the coupling cable and screw.
- 4.2.8. Stowing & Shipping
 - 4.2.8.1. All parts can fit into the FIST case. Take care to ensure that the cables are not crimped or damaged when closing the case cover.
 - 4.2.8.2. For shipping over a long distance, the internal battery should be completely discharged overnight. It is advisable to disconnect the pulser DC power and trigger cables on both ends for shipping.
 - 4.2.8.3. When transporting by hand or within a city area, the battery can be left charged. The user should exercise best judgment to leave alone or disconnect the interface cables between the GPS receiver and the pulser.

4.3. Maintenance

- 4.3.1. While designed for outdoor use, FIST should be stored indoor and at room temperature.
- 4.3.2. FIST is battery operated. The main battery is charged through the AC power. Some of the GPS solution parameters are maintained by a separate smaller battery. The main battery can help maintain the charge in the smaller battery and improve operation. Whenever practical, FIST should be maintained in a fully charged state. The full main battery will not only ensure FIST's availability at short notice, but also help retain previous GPS solution and shorten the GPS lock time.